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(54) **SEMICONDUCTOR LIGHT-EMITTING DEVICE**

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H01L 33/22 (2010.01)
H01L 33/46 (2010.01)

(52) **U.S. Cl.**

CPC **H01L 33/382** (2013.01); **H01L 33/22** (2013.01); **H01L 33/46** (2013.01)

(58) **Field of Classification Search**

CPC H01L 33/62; H01L 33/382; H01L 33/22; H01L 33/46

USPC 257/99
See application file for complete search history.

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(57) **ABSTRACT**

A semiconductor light-emitting device comprises a semiconductor stack comprising a side, a first surface and a second surface opposite to the first surface, wherein the semiconductor stack further comprises a conductive via extending from the first surface to the second surface; a transparent conductive layer formed on the second surface; a first pad portion and a second pad portion formed on the first surface and electrically connected to the semiconductor stack; and an insulating layer formed between the first pad portion and the semiconductor stack and between the second pad portion and the semiconductor stack.

20 Claims, 9 Drawing Sheets

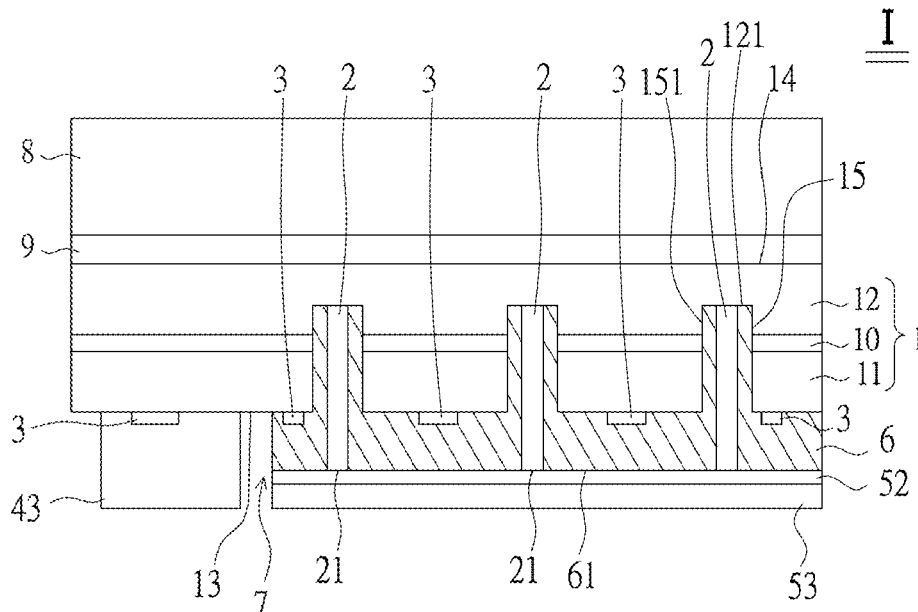


FIG. 2

FIG. 4

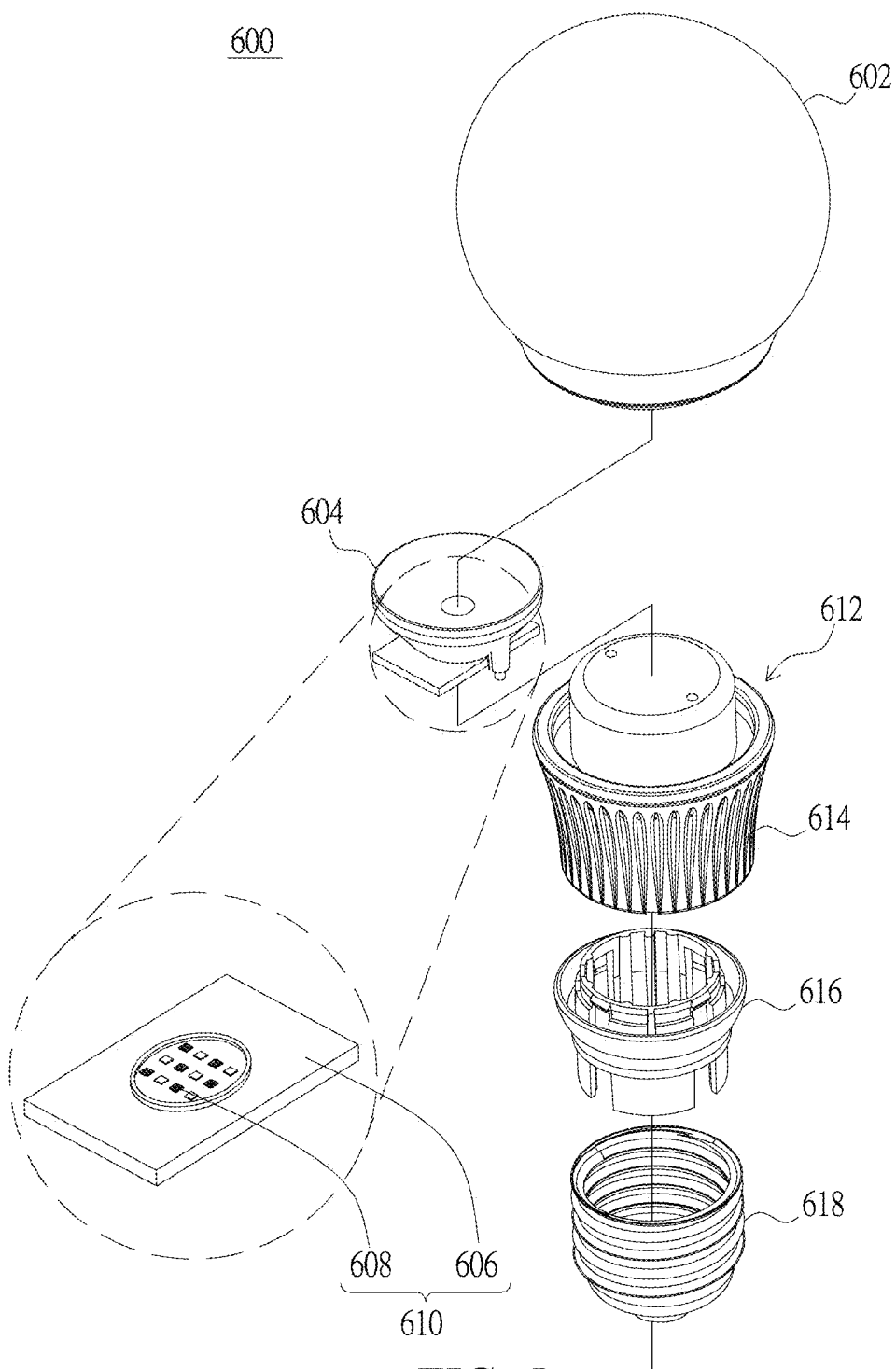


FIG. 5

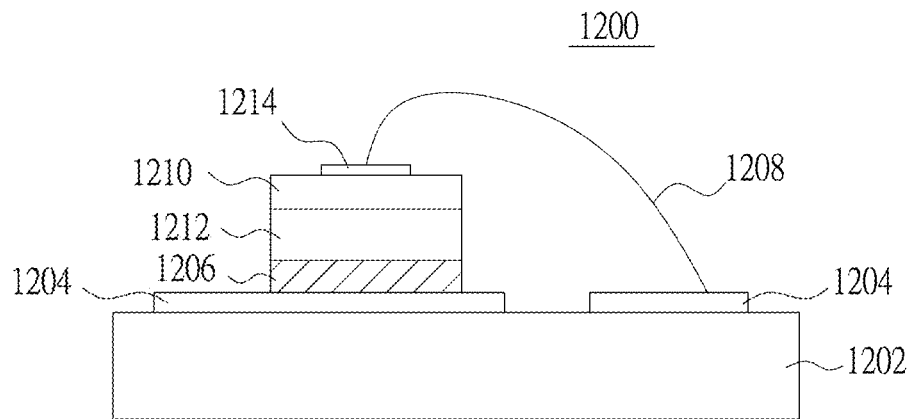


FIG. 6
(Prior Art)

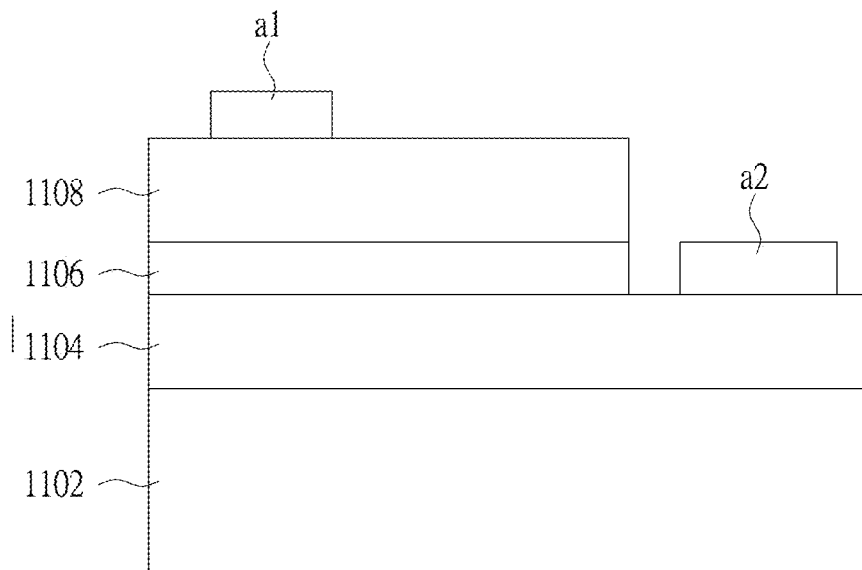


FIG. 7
(Prior Art)

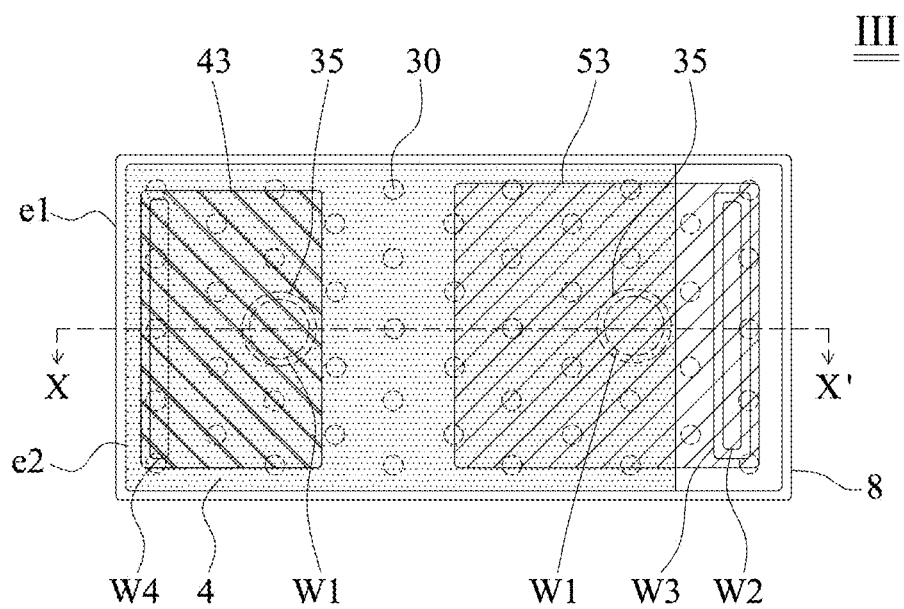
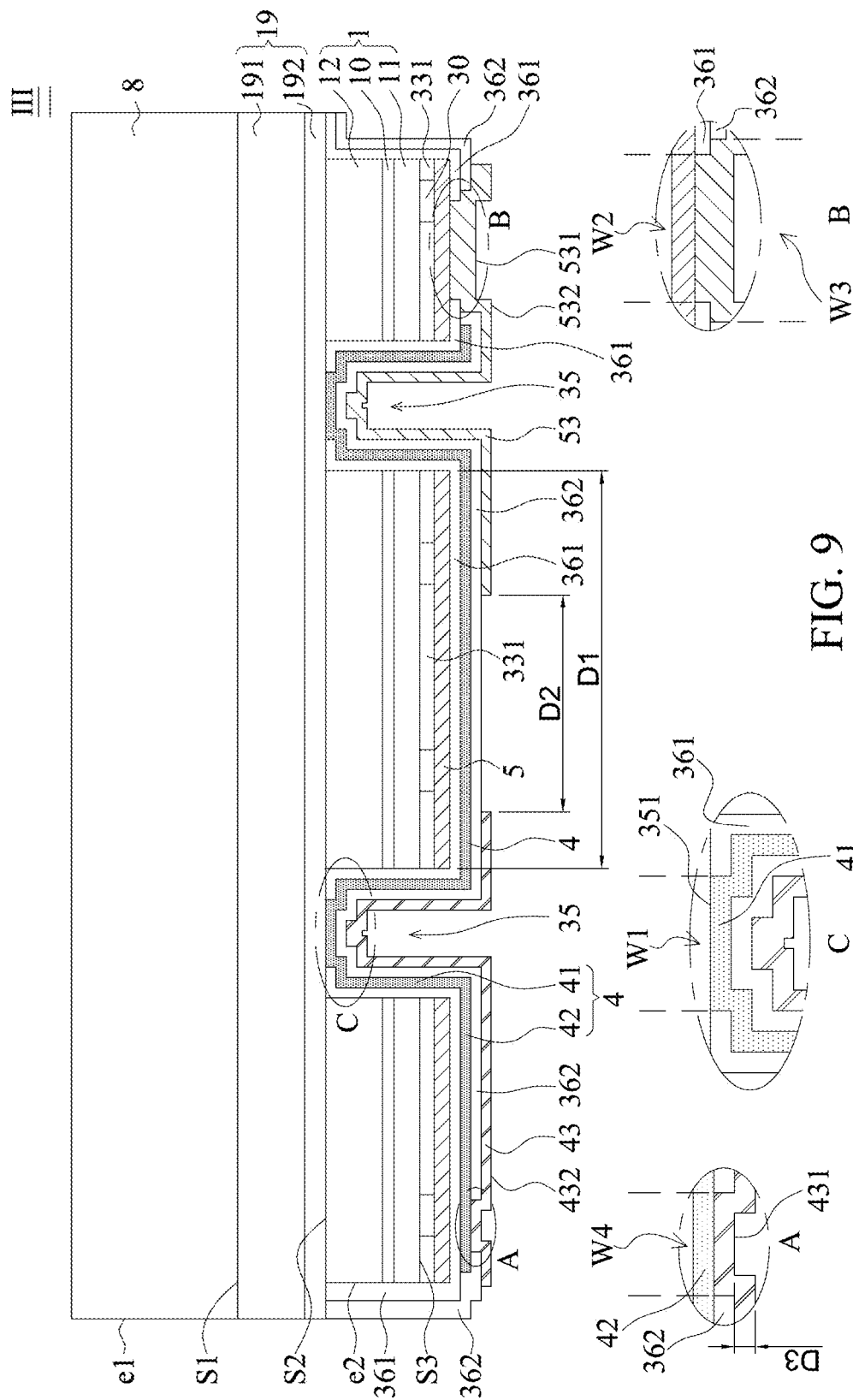


FIG. 8



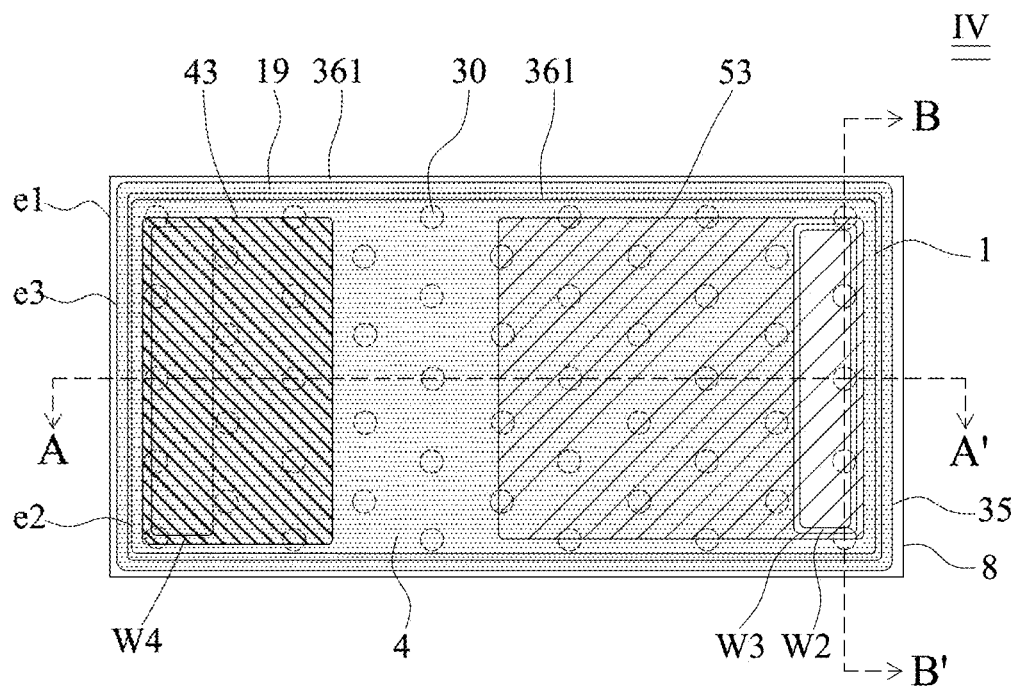
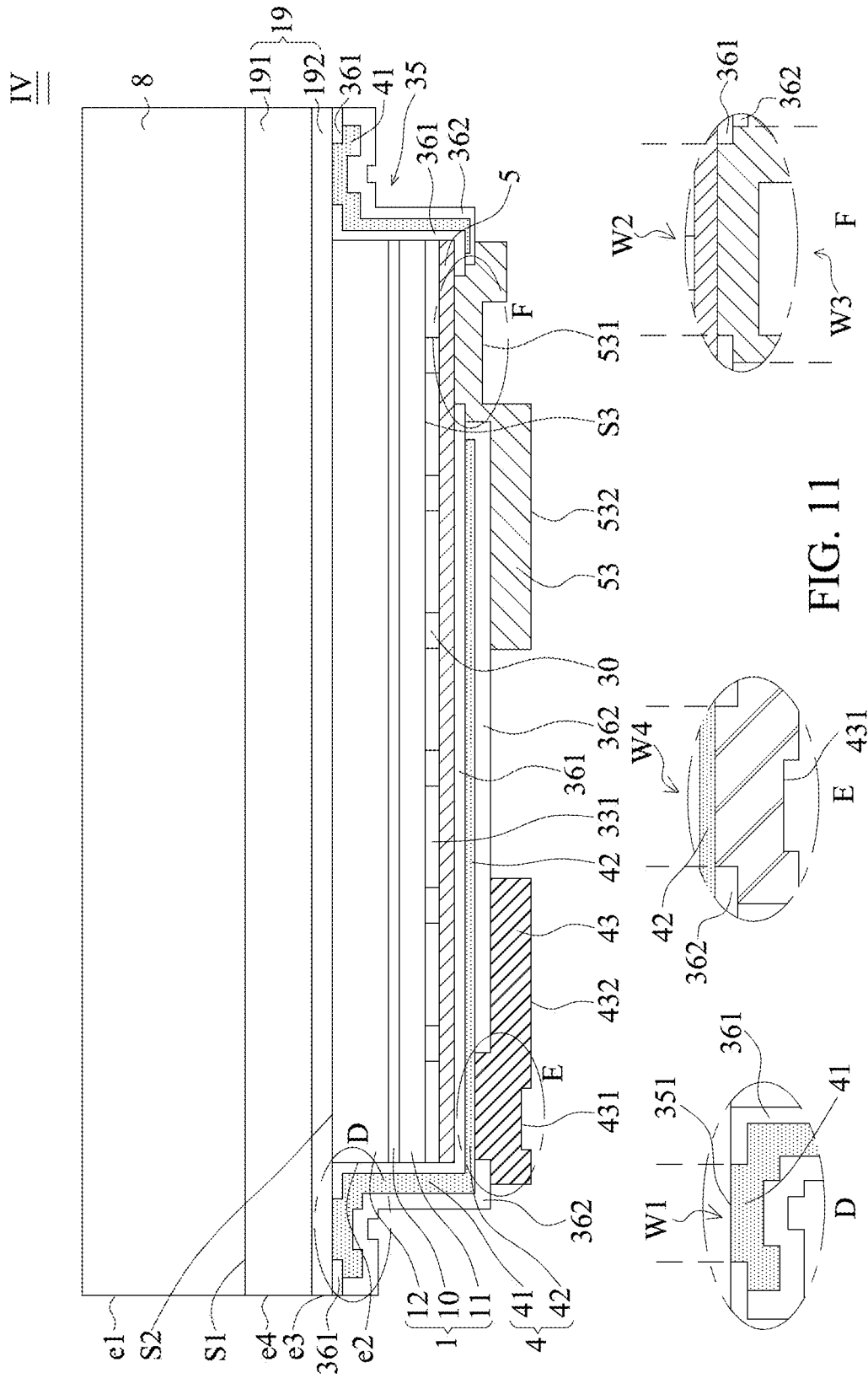


FIG. 10



IV

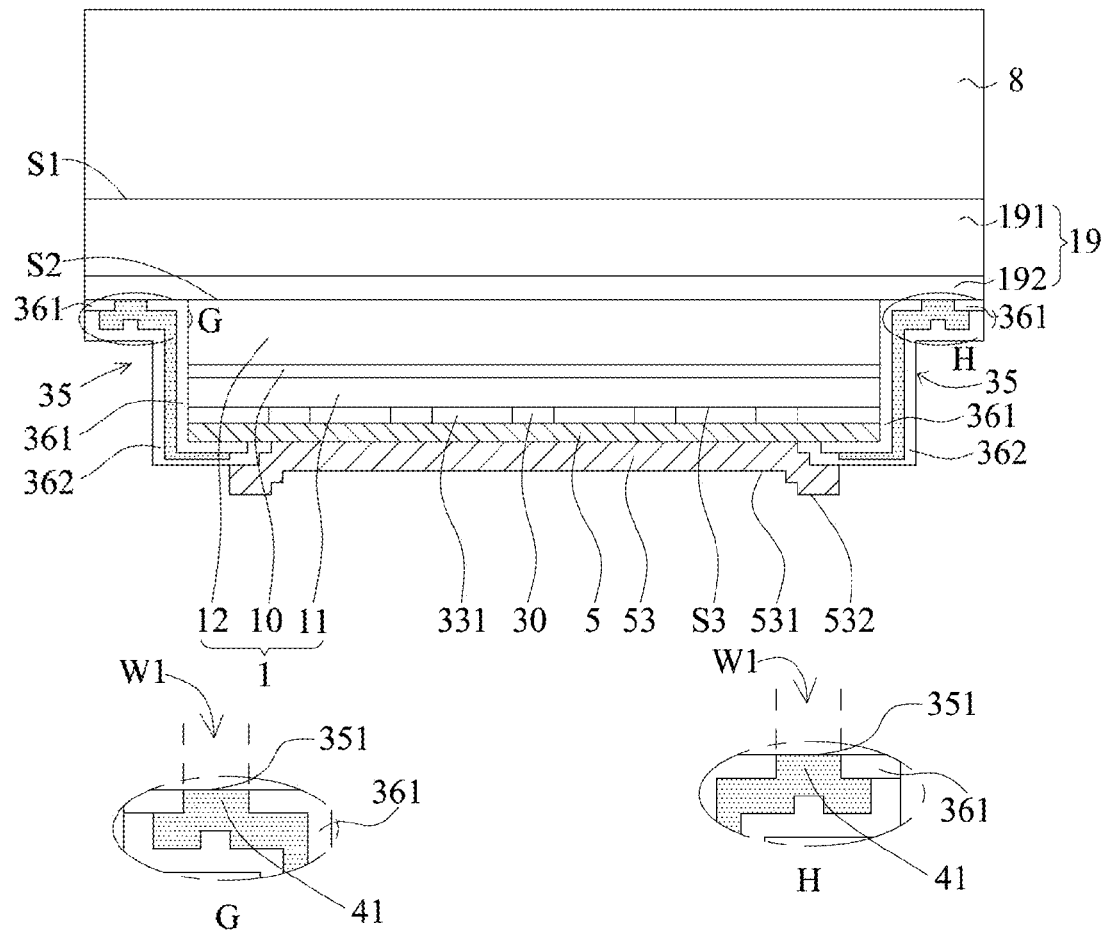


FIG. 12

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SEMICONDUCTOR LIGHT-EMITTING DEVICE

TECHNICAL FIELD

The application relates to a structure of a semiconductor light-emitting device, and more particularly, to a semiconductor light-emitting device comprising a conductive via.

REFERENCE TO RELATED APPLICATION

This application claims the right of priority based on TW Application Serial No. 102143409, filed on Nov. 27, 2013; TW Application Serial No. 103119845, filed on Jun. 6, 2014; TW Application Serial No. 103124091, filed on Jul. 11, 2014, and the content of which are hereby incorporated by reference in their entireties.

DESCRIPTION OF BACKGROUND ART

Light-emitting diode (LED) is widely applied to optical display apparatus, traffic lights, data storage apparatus, communication apparatus, lighting apparatus, and medical equipment. As shown in FIG. 7, a conventional LED comprises an n-type semiconductor layer 1104, an active layer 1106, and a p-type semiconductor layer 1108 sequentially formed on a substrate 1102. Portions of the p-type semiconductor layer 1108 and the active layer 1106 are removed to expose a portion of the n-type semiconductor layer 1104. A p-type electrode a1 and an n-type electrode a2 are formed on the p-type semiconductor layer 1108 and the n-type semiconductor layer 1104 respectively. Because the n-type electrode a2 requires a sufficient surface for following process such as wire bonding, a substantial portion of the active layer 1106 has to be removed and the light extraction efficiency is therefore lowered.

Furthermore, the LED described above can be connected with other devices to form a light-emitting apparatus. FIG. 6 illustrates a diagram of a conventional light-emitting apparatus. As shown in FIG. 6, a light-emitting apparatus 1200 comprises a sub-mount 1202 having an electrical circuit 1204; a solder 1206 formed on the sub-mount 1202 to adhere the LED 1210 to the sub-mount 1202, and electrically connecting a substrate 1212 of the LED 1210 and the electrical circuit 1204 of the sub-mount 1202; and an electrical connecting structure 1208 electrically connecting an electrode 1214 of the LED 1210 and the electrical circuit 1204 of the sub-mount 1202, wherein the sub-mount 1202 can be a lead frame or a large scaled mounting substrate suitable for the design of the electrical circuit of the light-emitting apparatus and improving heat dissipation.

SUMMARY OF THE APPLICATION

A semiconductor light-emitting device comprises a semiconductor stack comprising a first semiconductor layer, a second semiconductor layer, and an active layer formed between the first semiconductor layer and the second semiconductor layer, wherein the semiconductor stack comprises a first surface; a plurality of depressions penetrating from the first surface, through the first semiconductor layer and the active layer to expose the second semiconductor layer; a first contact structure formed on the first surface to ohmically contact the first surface; a second contact structure formed in the plurality of depressions to ohmically contact the second semiconductor layer; a first pad portion formed on the first surface to electrically connect the first semiconductor layer

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by the first contact structure; and a second pad portion formed on the first surface to electrically connect the second semiconductor layer by the second contact structure, wherein the first contact structure comprises a plurality of extension electrodes, a part of the second contact structure is formed between the plurality of extension electrodes.

A semiconductor light-emitting device comprises a semiconductor stack comprising a side, a first surface, and a second surface opposite to the first surface, wherein the semiconductor stack comprises a conductive via extending from the first surface to the second surface; a transparent conductive layer formed on the second surface; a first pad portion and a second pad portion formed on the first surface to electrically connect to the semiconductor stack; and an insulating layer formed between the first pad portion and the semiconductor stack, and between the second pad portion and the semiconductor stack.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a structure diagram of a semiconductor light-emitting device I in accordance with a first embodiment of the present application;

FIG. 2 illustrates a top view of the semiconductor light-emitting device I in accordance with the first embodiment of the present application;

FIG. 3 illustrates a diagram of a semiconductor light-emitting device II in accordance with a second embodiment of the present application;

FIG. 4 illustrates a top view of the semiconductor light-emitting device II in accordance with the second embodiment of the present application;

FIG. 5 illustrates a structure diagram in accordance with another embodiment of the present application;

FIG. 6 illustrates a structure diagram of a conventional light-emitting apparatus;

FIG. 7 illustrates a cross-sectional view of a conventional LED;

FIG. 8 illustrates a top view of a semiconductor light-emitting device III in accordance with another embodiment of the present application;

FIG. 9 illustrates a cross-sectional view along line X-X' of FIG. 8;

FIG. 10 illustrates a top view of a semiconductor light-emitting device IV in accordance with another embodiment of the present application;

FIG. 11 illustrates a cross-sectional view along line A-A' of FIG. 10; and

FIG. 12 illustrates a cross-sectional view along line B-B' of FIG. 10.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The embodiment of the application is illustrated in detail, and is plotted in the drawings. The same or the similar part is illustrated in the drawings and the specification with the same number.

First Embodiment

FIG. 1 illustrates a structure diagram of a semiconductor light-emitting device I in accordance with a first embodiment of the present application. The semiconductor light-emitting device I is a flip chip type light-emitting diode device comprising a semiconductor stack having depressions. The semiconductor light-emitting device I comprises a semiconductor

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stack 1 comprising a first surface 13 and a second surface 14 opposite to the first surface 13. The semiconductor stack 1 comprises a first semiconductor layer 11, a second semiconductor layer 12, and an active layer 10 formed between the first semiconductor layer 11 and the second semiconductor layer 12, wherein the first surface 13 is the surface of the first semiconductor layer 11 and the second surface 14 is the surface of the second semiconductor layer 12. The first semiconductor layer 11 and the second semiconductor layer 12 comprise different conductivity types, electricity, polarity, or dopant elements for providing electrons and holes. The active layer 10 is formed between the first semiconductor layer 11 and the second semiconductor layer 12. The active layer 10 converts electrical energy to optical energy. The dominant wavelength of the light is adjusted by changing physical and chemical compositions of one or more layers in the semiconductor stack 1. The material of the semiconductor stack 1 comprises aluminum gallium indium phosphide (AlGaInP), aluminum gallium indium nitride (AlGaInN), or zinc oxide (ZnO). The active layer 10 comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MQW) structure. Specifically, the active layer 10 comprises i-type, p-type, or n-type semiconductor. The active layer 10 emits light when an electrical current passes through the semiconductor stack 1. When the active layer 10 comprises AlGaInP based material, the active layer 10 emits amber series light, such as red light, orange light, or yellow light; when the active layer 10 comprises AlGaInN based material, the active layer 10 emits blue or green light. The present embodiment illustrates the semiconductor stack 1 with aluminum gallium indium phosphide (AlGaInP) based material.

A first contact structure 3 is formed on the first surface 13 to ohmically contact the first semiconductor layer 11, and a first pad portion 43 is formed on a part of the first contact structure 3. When the electrical current is injected into the first pad portion 43, the electrical current is conducted to an area of the first semiconductor layer 11 not covered by the first pad portion 43 through the first contact structure 3 for improving the current spreading. FIG. 2 illustrates a top view of the semiconductor light-emitting device I. The first pad portion 43 is formed on a side of the semiconductor light-emitting device I, and the shape of the first contact structure 3 comprises a plurality of finger electrodes extending from an area under the first pad portion 43 to another side opposite to that of the first pad portion 43 for spreading the current to all areas of the semiconductor stack 1. The material of the first pad portion 43 comprises titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof; the material of the first contact structure 3 comprises gold (Au), germanium (Ge), beryllium (Be), or an alloy thereof.

A plurality of depressions 15 is formed in the semiconductor stack 1, and each depression 15 penetrates from the first surface 13 of the first semiconductor layer 11, through the first semiconductor layer 11 and the active layer 10, and into the second semiconductor layer 12 to expose a plurality of surfaces 121 on the second semiconductor layer 12. A plurality of second contact structures 2 is formed in the plurality of depressions 15 to ohmically contact the plurality of surfaces 121. A smallest distance between the second contact structure 2 and the first contact structure 3 ranges between 10 μm and 100 μm . A length of the second contact structure 2 is longer than a depth of the depression 15, thus the second contact structure 2 protrudes the first surface 13. An insulating layer 6 is formed between the second contact structure 2 and a sidewall 151 of the depression 15. The insulating layer 6 separates the second contact structure 2 and the sidewall 151

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to avoid of the second contact structure 2 directly contacting the active layer 10 and the first semiconductor layer 11. In the embodiment, the plurality of depressions 15 is a plurality of vias. As shown in the top view of the first embodiment in FIG. 2, the plurality of depressions 15 is formed between a plurality of extension electrodes 33 of the first contact structure 3, and is arranged along an extending direction of the extension electrode 33. The second contact structure 2 comprises a plurality of conductive rods 22 disposed in the plurality of depressions 15 respectively. A smallest distance between the conductive rod 22 and the extension electrode 33 ranges between 10 μm and 100 μm . The insulating layer 6 not only fills a space between the second contact structure 2 and the sidewall 151, but also covers a part of the first contact structure 3 which is formed on the first surface 13. The insulating layer 6 covers a part of the second contact structure 2 protruding from the first surface 13, and exposes a contact surface 21 of the second contact structure 2. The insulating layer 6 and the contact surface 21 of the second contact structure 2 form a flat surface 61. The material of the second contact structure 2 comprises germanium (Ge), beryllium (Be), gold (Au), or an alloy thereof to ohmically contact the second semiconductor layer 12. The insulating layer 6 permits the light emitted from the active layer 10 to transmit thereof. In another embodiment, the first surface 13 can be a rough surface which reduces the total internal reflection of the light passing through the insulating layer 6 and the first surface 13. The material of the insulating layer 6 comprises organic materials, such as benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy resin, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymers; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

A reflective layer 52 covers all of the surface 61 and contacts all of the contact surfaces 21 of the second contact structure 2. The material of the reflective layer 52 comprises metal material with high reflectivity, such as silver (Ag), gold (Au), aluminum (Al), titanium (Ti), chromium (Cr), copper (Cu), nickel (Ni), platinum (Pt), or an alloy thereof.

A second pad portion 53 covers the reflective layer 52 to connect the reflective layer 52. The second pad portion 53 conducts the electrical current from the external power source into the semiconductor light-emitting device I, wherein the electrical current sequentially flows through the reflective layer 52, the second contact structure 2 and the semiconductor stack 1, and flows out from the first contact structure 3 and the first pad portion 43. The material of the second pad portion 53 comprises titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof. A space 7 is formed between the first pad portion 43 and the second pad portion 53 to separate the first pad portion 43 and the second pad portion 53. A width of the space 7 ranges between 70 μm and 250 μm . When the semiconductor light-emitting device I comprises a square shape with a side of 12 mil, the area of the first pad portion 43 and the second pad portion 53 is 15%~40% of the area of the semiconductor light-emitting device I; when the semiconductor light-emitting device I comprises a square shape with a side of 28 mil, the area of the first pad portion 43 and the second pad portion 53 is 60%~92% of the area of the semiconductor light-emitting device I; when the semiconductor light-emitting device I comprises a square shape with a side of 40 mil, the area of the first pad portion 43 and the second pad portion 53 is 75%~95% of the area of the semiconductor light-emitting device I.

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An adhesive layer 9 covers the second surface 14, and the substrate 8 is bonded to the second surface 14 by the adhesive layer 9. The light emitted from the active layer 10 can transmit through the adhesive layer 9 and the substrate 8. In another embodiment, the second surface 14 is a rough surface which reduces the total internal reflection of the light transmitting through the adhesive layer 9 and the second surface 14. The refractive index of the adhesive layer 9 preferably ranges between the refractive index of the second semiconductor layer 12 and the refractive index of the substrate 8, and the refractive index of the substrate 8 is preferably smaller than the refractive index of the adhesive layer 9. In the embodiment, the refractive index of the adhesive layer 9 ranges between 1.77 and 3.3, and the refractive index of the substrate 8 ranges between 1 and 1.77. The material of the adhesive layer 9 comprises material which is transparent with respect to the light emitted from the active layer 10, including organic materials, such as Sub, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer, inorganic materials, such as silicone, glass; dielectric material, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2). A material of the substrate 8 comprises transparent material which is transparent with respect to the light emitted from the active layer 10, such as gallium arsenide (GaAs), gallium phosphide (GaP), gallium nitride (GaN), sapphire, diamond, glass, quartz, acrylic, zinc oxide (ZnO), or aluminum nitride (AlN).

Second Embodiment

FIG. 3 illustrates a diagram of a semiconductor light-emitting device II in accordance with a second embodiment of the present application. The semiconductor light-emitting device II is a flip chip type light-emitting diode device comprising a semiconductor stack 1 having depressions. The semiconductor light-emitting device II comprises the semiconductor stack 1 having a first surface 13 and a second surface 14 opposite to the first surface 13. The semiconductor stack 1 comprises a first semiconductor layer 11, a second semiconductor layer 12, and an active layer 10 formed between the first semiconductor layer 11 and the second semiconductor layer 12, wherein the first surface 13 is the surface of the first semiconductor layer 11 and the second surface 14 is the surface of the second semiconductor layer 12. The first semiconductor layer 11 and the second semiconductor layer 12 comprises different conductivity types, electricity, polarity, or dopant elements for providing electrons and holes. The active layer 10 is formed between the first semiconductor layer 11 and the second semiconductor layer 12. The active layer 10 converts electrical energy to optical energy. The dominant wavelength of the light is adjusted by changing physical and chemical compositions of one or more layers in the semiconductor stack 1. The material of the semiconductor stack 1 comprises aluminum gallium indium phosphide (AlGaInP), aluminum gallium indium nitride (AlGaInN), or zinc oxide (ZnO). The active layer 10 comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MQW) structure. Specifically, the active layer 10 comprises i-type, p-type, or n-type semiconductor. The active layer 10 emits light when an electrical current passes through the semiconductor stack 1. When the active layer 10 comprises AlGaInP based material, the active layer 10 emits amber

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series light, such as red light, orange light, or yellow light; when the active layer 10 comprises AlGaInN based material, the active layer 10 emits blue or green light. The present embodiment illustrates the semiconductor stack 1 with aluminum gallium indium phosphide (AlGaInP) based material.

In the embodiment, the depression 15 is formed in the semiconductor stack 1, penetrates from the first surface 13 of the first semiconductor layer 11, through the first semiconductor layer 11, the active layer 10, and into the second semiconductor layer 12 to expose a plurality of surfaces 121 on the second semiconductor layer 12. As shown in the top view of the semiconductor light-emitting device II of FIG. 4 in accordance with the second embodiment of the present application, the depression 15 comprises a path 15A formed on a side 16 of the semiconductor stack 1, a longitudinal path 15B, or a transversal path 15C, wherein the path 15A, the path 15B, and the path 15C are connected to each other. The second contact structure 2 is formed in the depression 15, continuously along the path 15A, the path 15B, and the path 15C to ohmically contact the surface 121 for uniformly spreading the electrical current on the second semiconductor layer 12. An insulating layer 62 conformably covers the second contact structure 2, the path 15B, the path 15C, and the first surface 13 adjacent to the path 15B and the path 15C, but not covers the first contact structure 3. The insulating layer 62 separates the second contact structure 2 and the sidewall 151 to avoid of the second contact structure 2 directly contacting the active layer 10 and the first semiconductor layer 11. The material of the second contact structure 2 comprises germanium (Ge), beryllium (Be), gold (Au), or an alloy thereof to ohmically contact the second semiconductor layer 12. The insulating layer 62 permits the light emitted from the active layer 10 to transmit thereof. The material of the insulating layer 62 comprises organic materials, such as benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

In the embodiment, the first surface 13 can be a rough surface which reduces the total internal reflection of the light passing through the first surface 13 and the insulating layer 62. The method of forming the rough surface comprises wet etch, such as soaking in acidic or alkaline etching solution, or dry etching, such as ICP. The contact structure 3 is formed on the first surface 13 to ohmically contact the first semiconductor layer 11. As shown in FIG. 4, the shape of the first contact structure 3 comprises a pattern, such as point, line, circle, ellipse, square, or rectangular. In the embodiment, the first contact structure 3 is distributed on the first semiconductor layer 11 in a shape of a plurality of squares comprising a big square 31 and a small square 32, which are independent to each other and not directly contact with each other. The periphery of each square is surrounded by the second contact structure 2. The material of the first contact structure 3 comprises gold (Au), germanium (Ge), beryllium (Be), or an alloy thereof to ohmically contact the first semiconductor layer 11.

A transparent conductive layer 55 conformably covers the first surface 13, the first contact structure 3, and the insulating layer 62. A reflective layer 52 conformably covers the transparent conductive layer 55. The transparent conductive layer 55 comprises transparent conductive material and a thickness ranging between 1 μm and 10 μm for adhering with the reflective layer 52 and avoid of the reflective layer 52 from

peeling. The material of the reflective layer 52 comprises metal material with high reflectivity, such as silver (Ag), gold (Au), aluminum (Al), titanium (Ti), chromium (Cr), copper (Cu), nickel (Ni), platinum (Pt), or an alloy thereof, to reflect the light emitted from the active layer 10 toward the second surface 14.

A patterned insulating layer 63 conformably covers the reflective layer 52, forms along the periphery of the reflective layer 52 to cover the sidewall 151 of the path 15A. The insulating layer 63 comprises a via 631 exposing the reflective layer 52. The insulating layer 63 comprises non-conductive material organic materials, such as Sub, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

A first pad portion 43 and a second pad portion 53 are formed on the insulating layer 63. A bonding surface 431 of the first pad portion 43 and a bonding surface 532 of the second pad portion 53 are on the same planar surface by forming the insulating layer 63 under the first pad portion 43 and the second pad portion 53. A space 7 is formed between the first pad portion 43 and the second pad portion 53 to separate the first pad portion 43 and the second pad portion 53. In the embodiment, a width of the space 7 ranges between 70 μm and 250 μm . When the semiconductor light-emitting device comprises a square shape with a side of 12 mil, the area of the first pad portion 43 and the second pad portion 53 is 15%–80% of the area of the semiconductor light-emitting device; when the semiconductor light-emitting device comprises a square shape with a side of 28 mil, the area of the first pad portion 43 and the second pad portion 53 is 60%–92% of the area of the semiconductor light-emitting device; when the semiconductor light-emitting device comprises a square shape with a side of 40 mil, the area of the first pad portion 43 and the second pad portion 53 is 75%–95% of the area of the semiconductor light-emitting device. The first pad portion 43 directly contacts the reflective layer 52 through the via 631, the second pad portion 53 is separated from the reflective layer 52 by the insulating layer 63. The second pad portion 53 comprises a connecting part 531 covering the path 15A to directly connect the second contact structure 2. The connecting part 531 covers the insulating layer 63 of the sidewall 151 of the path 15A to avoid of directly contacting the active layer 10 and the first semiconductor layer 11. The first pad portion 43 and the second pad portion 53 conduct the electrical current from the external power source into the semiconductor light-emitting device II for emitting light. The electrical current flows into the first pad portion 43, through the hole 631, the reflective layer 52, into the semiconductor stack 1 by way of the areas having lower contact resistance which is between the first contact structure 3 and the first semiconductor layer 11, the electrical current sequentially flows through the first semiconductor layer 11, the active layer 10, and the second semiconductor layer 12, and flows out the second pad portion 53 by the second contact structure 2. The material of the first pad portion 43 and the second pad portion 53 comprise titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof. In another embodiment, the insulating layer 63 is disposed only between the second pad portion 53 and the reflective layer 52, and the first pad portion 43 directly contacts the reflective layer 52 for increasing the heat dissipation efficiency. The first pad portion 43 can be further processed

through evaporation for forming the bonding surface 431 of the first pad portion 43 and the bonding surface 532 of the second pad portion 53 on the same planar surface.

An adhesive layer 9 covers the second surface 14, and the substrate 8 is bonded to the second surface 14 by the adhesive layer 9. The light emitted from the active layer 10 can transmit through the adhesive layer 9 and the substrate 8. The second surface 14 can form a rough surface which reduces the total internal reflection and increases the light extraction efficiency when the light transmits through the adhesive layer 9 and the second surface 14. The method of forming the rough surface comprises wet etch, such as soaking in acidic or alkaline etching solution, or dry etching, such as ICP. The refractive index of the adhesive layer 9 preferably ranges between the refractive index of the second semiconductor layer 12 and the refractive index of the substrate 8, and the refractive index of the substrate 8 is preferably smaller than the refractive index of the adhesive layer 9. In the present embodiment, the refractive index of the adhesive layer 9 ranges between 1.77 and 3.3, and the refractive index of the substrate ranges between 1 and 1.77. The material of the adhesive layer 9 comprises material which is transparent with respect to the light emitted from the active layer 10, including organic materials, such as Sub, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2). A material of the substrate 8 comprises transparent material which is transparent with respect to the light emitted from the active layer 10, such as gallium arsenide (GaAs), gallium phosphide (GaP), gallium nitride (GaN), sapphire, diamond, glass, quartz, acrylic, zinc oxide (ZnO), or aluminum nitride (AlN).

FIG. 8 illustrates a top view of a semiconductor light-emitting device III in accordance with another embodiment of the present application. FIG. 9 illustrates a cross-sectional view along line X-X' of FIG. 8. The semiconductor light-emitting device III is a flip chip type light-emitting diode device. As shown in FIG. 9, the semiconductor light-emitting device III comprises a semiconductor stack 1 comprising a first surface S3 and a second surface S2 opposite to the first surface S3. The semiconductor stack 1 comprises a first semiconductor layer 11, a second semiconductor layer 12, and an active layer 10 formed between the first semiconductor layer 11 and the second semiconductor layer 12, wherein the first surface 13 is the surface of the first semiconductor layer 11 and the second surface 14 is the surface of the second semiconductor layer 12. The first semiconductor layer 11 and the second semiconductor layer 12, such as cladding layers or confinement layers, comprise different conductivity types, electricity, polarity, or dopant elements to provide electrons and holes. The active layer 10 is formed between the first semiconductor layer 11 and the second semiconductor layer 12 so the electrons and the holes combine in the active layer 10 under an electrical current to convert electrical energy to optical energy for emitting a light. The dominant wavelength of the light is adjusted by changing physical and chemical compositions of one or more layers in the semiconductor stack 1. The material of the semiconductor stack 1 comprises group III-V semiconductor materials, such as $\text{Al}_x\text{In}_y\text{Ga}_{(1-x-y)}\text{N}$ or $\text{Al}_x\text{In}_y\text{Ga}_{(1-x-y)}\text{P}$, wherein $0 \leq x, y \leq 1$; ($x+y$) ≤ 1 . In accordance with the material of the active layer 10, the semiconductor stack 1 can emit a red light with a dominant wavelength between 610 nm and 650 nm, a green light with a

dominant wavelength between 530 nm and 570 nm, or a blue light with a dominant wavelength between 450 nm and 490 nm. The active layer **10** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MQW) structure. The material of the active layer **10** comprises i-type, p-type, or n-type semiconductor.

A plurality of contact structures is uniformly distributed on the first surface S3 of the semiconductor stack **1** to ohmically contact the first semiconductor layer **11** for spreading the current on the first semiconductor layer **11**. For example, a metal layer can be deposited on the first surface S3 of the semiconductor stack **1** and patterned to form a plurality of contact structures **30**. The material of the contact structure **30** comprises gold (Au), germanium (Ge), beryllium (Be), or an alloy thereof. The shape of the contact structure **30** comprises circle or polygon. As shown in the top view of the semiconductor light-emitting device III of FIG. **8**, the shape of the contact structure **30** is circle and a plurality of contact structures **30** is arranged into a plurality of rows on the semiconductor stack **1**, wherein the plurality of contact structures **30** on adjacent two rows are staggered.

A first reflective layer **331** comprising low refractive index materials is formed on the first surface S3 of the semiconductor stack **1**, and/or between the plurality of contact structures **30**. Furthermore, the plurality of contact structures **30** can be formed between the first reflective layer **331** and the semiconductor stack **1**. Because the refractive index of the group III-V semiconductor materials is between 2 and 4, a material having a refractive index lower than that of the group III-V semiconductor materials is chosen to totally reflect the light emitted from the active layer **10** between the first surface S3 and the first reflective layer **331** for increasing the light extraction efficiency of the semiconductor light-emitting device III. The low refractive index material comprises oxide, fluoride, or metal oxide. The fluoride comprises magnesium fluoride (MgF₂) or calcium fluoride (CaF₂). Metal oxide comprises titanium oxide (TiO₂), tantalum oxide (Ta₂O₅), tellurium dioxide (TeO₂), yttrium oxide (Y₂O₃), hafnium oxide (HfO₂), aluminum oxide (Al₂O₃), indium zinc oxide (IZO), or indium tin oxide (ITO).

In order to increase the light extraction efficiency of the semiconductor light-emitting device III, the first surface S3 of the semiconductor stack **1** can be a rough surface, and/or a second reflective layer **5** is formed on the first surface S3. The method for forming the rough surface comprises etching, polishing, or printing. The etching method comprises wet etch, such as soaking in acidic or alkaline etching solution, or dry etching, such as ICP. The structure of the second reflective layer **5** can be one or more layers. The material of the second reflective layer **5** comprises metal material with high reflectivity, such as silver (Ag), gold (Au), aluminum (Al), titanium (Ti), chromium (Cr), copper (Cu), nickel (Ni), platinum (Pt), or an alloy thereof. The high reflectivity is 80% or above with respect to the dominant wavelength of the light emitted from the semiconductor light-emitting device III. The second reflective layer **5** is more away from the semiconductor stack **1** than the first reflective layer **331** so the light not reflected by the first reflective layer **331** can be further reflected by the second reflective layer **5**. As shown in FIG. **9**, the second reflective layer **5** contacts with the first reflective layer **331** and/or the plurality of contact structures **30** for forming electrical connection when electrical current is injected.

A transparent conductive layer **19** is formed on the second surface S2 of the semiconductor stack **1** and electrically connected to the semiconductor stack **1** when electrical current is injected. The material of the transparent conductive layer **19**

comprises transparent material which is transparent to the light emitted from the active layer **10**. In order to reduce the possibility of total internal reflection of the light emitted from the active layer **10** on the second surface S2, the transparent conductive layer **19** comprises non group III-V semiconductor materials, wherein the refractive index of the material of the transparent conductive layer **19** is lower than that of the semiconductor stack **1**, and the structure of the transparent layer **19** can be one or more layers, for example, comprising a first transparent conductive layer **191** and a second transparent conductive layer **192**. Specifically, when the transparent conductive layer **19** is a structure of multi layers, the first transparent conductive layer **191**, which is more away from the semiconductor stack **1** than other transparent conductive layers, comprises material for improving lateral current spreading, for example, indium zinc oxide (IZO). The second transparent conductive layer **192**, which is more closer to the semiconductor stack **1** than other transparent conductive layers, comprises material for forming ohmically contact with the second semiconductor layer **12**, for example, indium tin oxide (ITO).

In order to increase the light extraction efficiency of the semiconductor light-emitting device III, the second surface S2 of the semiconductor stack **1** can be a rough surface to reduce total internal reflection. The method for forming the rough surface comprises etching, polishing, or printing. The etching method comprises wet etch, such as soaking in acidic or alkaline etching solution, or dry etching, such as ICP.

In other embodiments of the present application, a substrate **8** can be optionally formed on the semiconductor stack **1**. The substrate **8** can be bonded to the second surface S2 of the semiconductor stack **1** by the transparent conductive layer **19**. The substrate **8** comprises transparent material which is transparent to the light emitted from the active layer **10**, such as gallium arsenide (GaAs), gallium phosphide (GaP), gallium nitride (GaN), sapphire, diamond, glass, quartz, acrylic, zinc oxide (ZnO), or aluminum nitride (AlN). In order to reduce the total internal reflection of the light emitted from the active layer **10** on the interface S1 between the substrate **8** and the transparent conductive layer **19**, the refractive index of the material of the substrate **8** is smaller than that of the transparent conductive layer **19**, and the refractive index of the transparent conductive layer **19** is between the refractive index of the substrate **8** and the refractive index of the semiconductor stack **1**. Concerning the process yield, a side e1 of the substrate **8** can be planar with a side e2 of the semiconductor stack **1**, or the side e1 of the substrate **8** protrudes the side e2 of the semiconductor stack **1**, as shown in FIG. **9**.

In an embodiment of the present application, the semiconductor stack **1** comprises a conductive via **35** extending from the first surface S3 to the second surface S2. As shown in FIG. **8**, the semiconductor light-emitting device III comprises a plurality of conductive vias **35**, wherein the plurality of conductive vias **35** is separated from each other from a top view of the semiconductor light-emitting device III, and each of the plurality of conductive vias **35** is surrounded by the semiconductor stack **1**. As shown in FIG. **9**, the plurality of conductive vias **35** penetrates from the first surface S3 of the semiconductor stack **1**, through the semiconductor stack **1** by removing a part of the semiconductor stack **1**. In a variant of the embodiment, an end **351** of the conductive via **35** exposes on the second surface S2 of the semiconductor stack **1** as shown in FIG. **9**. In another variant of the embodiment, the end **351** of the conductive via **35** extends a depth into the transparent conductive layer **19** (not shown). The forming position of the conductive via **35** is staggered with the forming position of the contact structure **30**, as shown in FIG. **8**, the plurality of

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contact structures 30 surrounds the conductive via 35 and is disposed on the periphery of the conductive via 35.

A first insulating layer 361 can be deposited on the semiconductor stack 1 and in the conductive via 35 through evaporation. A part of the first insulating layer 361 covering the end 351 of the conductive via 35 and a part of the first insulating layer 361 covering the second reflective layer 5 can be removed through patterning to form a first opening W1 on the end 351 of the conductive via 35 and expose the transparent conductive layer 19, and to form a second opening W2 on the second reflective layer 5 and expose the second reflective layer 5. The material of the first insulating layer 361 comprises non-conductive material comprising organic materials, such as Sub, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer, inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

As shown in FIG. 8 and FIG. 9, a conductive material, such as metal, is deposited in the conductive via 35 through evaporation or sputtering to cover the first opening W1 and cover a part of the first insulating layer 361 to form a connecting layer 4. The connecting layer 4 comprises a first connecting layer 41 formed in the conductive via 35 and a second connecting layer 42 formed on the first insulating layer 361, wherein the first connecting layer 41 surrounds the periphery of the conductive via 35, the first insulating layer 361 is formed between the semiconductor stack 1 and the first connecting layer 41 to electrically insulate the semiconductor stack 1 and the first connecting layer 41, and a plurality of connecting layers 41 formed in the plurality of conductive vias 35 is electrically connected to each other through the second connecting layer 42. As shown in FIG. 9, the end 351 of the plurality of conductive vias 35 is exposed on the second surface S2 of the semiconductor stack 1, the first opening W1 and the second opening W2 are formed on the second surface S2 and the first surface S3 respectively by patterning the first insulating layer 361, and the connecting layer 4 covers the first opening W1 and exposes the second opening W2. When the transparent conductive layer 19 comprises a structure of multi layers, for example, comprises the first transparent conductive layer 191 and the second transparent conductive layer 192, the end 351 of the conductive via 35 can extend into the first transparent conductive layer 191 which is more away from the semiconductor stack 1 than other transparent conductive layers. In view of the better lateral current spreading ability of the first transparent conductive layer 191, the current injected from the connecting layer 4 is uniformly spreads in the first transparent conductive layer 191 and conducted to the second semiconductor layer 12 through the second transparent conductive layer 192.

A second insulating layer 362 can be deposited on the semiconductor stack 1 by evaporation or sputtering. A part of the second insulating layer 362 covering the second connecting layer 42 and a part of the second insulating layer 362 covering the second reflective layer 5 can be removed through patterning to form a third opening W3 on the second reflective layer 5 and expose the second reflective layer 5, and to form a fourth opening W4 on the second connecting layer 42 and expose the second connecting layer 42. From the top view of the semiconductor light-emitting device III, the third opening W3 is larger than the second opening W2, the position of the third opening W3 and the position of the second opening W2 are overlapped, and the position of the fourth opening W4 and

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the position of the first opening W1 can be overlapped or staggered, as shown in FIG. 8. The material of the second insulating layer 362 comprises non-conductive material comprising organic materials, such as Sub, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

A first pad portion 43 and a second pad portion 53 are formed on the same side of the semiconductor stack 1. The first pad portion 43 is formed on partial surface of the second insulating layer 362 to cover the fourth opening W4 for electrically connecting to the connecting layer 4. In an embodiment of the present application, a metal material is deposited in the fourth opening W4 and the conductive via 35, the metal material is continuously deposited along the conductive via 35, the sidewall of the first insulating layer 361, and/or the second insulating layer 362 to cover partial surface of the second insulating layer 362 to form the first pad portion 43. As shown in the cross-sectional view of the semiconductor light-emitting device III, the first pad portion 43 comprises a first face 431 and a second face 432 protruding the first face 431, wherein the first face 431 and the second face 432 are approximately parallel with the first surface S3 of the semiconductor stack 1. A height D3 is formed between the first face 431 and the second face 432, and the height D3 is larger than or equal to a thickness of the second insulating layer 362.

As shown in FIG. 9, a part of the surface of the second reflective layer 5 is not covered by the first insulating layer 361 and/or the second insulating layer 362. The metal material can be evaporated in the conductive via 35, the second opening W2 and/or the third opening W3, and the metal material is continuously deposited along the conductive via 35, the sidewall of the first insulating layer 361 and/or the sidewall of the second insulating layer 362 to extend onto a part of the second insulating layer 362 for forming the second pad portion 53. As shown in the cross-sectional view of the semiconductor light-emitting device III of FIG. 9, the second pad portion 53 comprises a first face 531 and a second face 532 protruding the first face 531, wherein the first face 531 and the second face 532 are approximately parallel with the first surface S3 of the semiconductor stack 1. From a top view of the semiconductor light-emitting device III, the conductive via 35 is formed on an area covered by the first pad portion 43 and/or the second pad portion 53. In an embodiment of the present application, concerning the current spreading ability of the transparent conductive layer 19, one of the plurality of conductive vias 35 is formed in a region covered by the first pad portion 43 and another one of the plurality of conductive vias 35 is formed in a region covered by the second pad portion 53. The shortest distance D1 between the two conductive vias 35 is larger than the shortest distance D2 between the first pad portion 43 and the second pad portion 53 as shown in FIG. 9.

From the top view of the semiconductor light-emitting device III, the connecting layer 4 extends from the side e2 of the semiconductor stack 1 to the side of the conductive via 35 to overlap with the forming regions of the first pad portion 43 and the second pad portion 53, and cover the plurality of conductive vias 35 so as to connect the plurality of conductive vias 35 as shown in FIG. 8, or locally forms between the

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plurality of conductive vias **35** to connect the plurality of conductive vias **35** with a patterned structure (not shown), for example, line or mesh.

An electrical current from external power source can be injected from the first pad portion **43** and conducted to the second semiconductor layer **12** through the connecting layer **4** and the transparent conductive layer **19**. The material of the first pad portion **43** comprises titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof.

The second pad portion **53** is formed on a part of the contact structure **30**. When an electrical current from external power source is injected into the second pad portion **53**, the second pad portion **53** is electrically connected with the first semiconductor layer **11** through the contact structure **30**. The material of the second pad portion **53** comprises titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof. An area of the first pad portion **43** can be the same as or different from that of the second pad portion **53**.

FIG. **10** illustrates a top view of a semiconductor light-emitting device IV in accordance with another embodiment of the present application. FIG. **11** illustrates a cross-sectional view along line A-A' of FIG. **10**. FIG. **12** illustrates a cross-sectional view along line B-B' of FIG. **10**. The semiconductor light-emitting device IV is a flip chip type light-emitting diode device. As shown in FIG. **11** and FIG. **12**, the semiconductor light-emitting device IV comprises a semiconductor stack **1** comprising a first surface S3, a second surface S2 opposite to the first surface S3, and a side e2 connecting the first surface S3 and the second surface S2. The semiconductor stack **1** comprises a first semiconductor layer **11**, a second semiconductor layer **12**, and an active layer **10** formed between the first semiconductor layer **11** and the second semiconductor layer **12**, wherein the first surface S3 is the surface of the first semiconductor layer **11** and the second surface S2 is the surface of the second semiconductor layer **12**. The first semiconductor layer **11** and the second semiconductor layer **12** such as cladding layers or confinement layers comprise different conductivity types, electricity, polarity, or dopant elements to provide electrons and holes. The active layer **10** is formed between the first semiconductor layer **11** and the second semiconductor layer **12** so the electrons and the holes combine in the active layer **10** under an electrical current to convert electrical energy to optical energy for emitting a light. The dominant wavelength of the light is adjusted by changing physical and chemical compositions of one or more layers in the semiconductor stack **1**. The material of the semiconductor stack **1** comprises group III-V semiconductor materials, such as $\text{Al}_x\text{In}_y\text{Ga}_{(1-x-y)}\text{N}$ or $\text{Al}_x\text{In}_y\text{Ga}_{(1-x-y)}\text{P}$, wherein $0 \leq x, y \leq 1$; $(x+y) \leq 1$. In accordance with the material of the active layer **10**, the semiconductor stack **1** can emit a red light with a dominant wavelength between 610 nm and 650 nm, a green light with a dominant wavelength between 530 nm and 570 nm, or a blue light with a dominant wavelength between 450 nm and 490 nm. The active layer **10** comprises single heterostructure (SH), double heterostructure (DH), double-side double heterostructure (DDH), or multi-quantum well (MQW) structure. The material of the active layer **10** comprises i-type, p-type, or n-type semiconductor.

A plurality of contact structures **30** is uniformly distributed on the first surface S3 of the semiconductor stack **1** to ohmically contact the first semiconductor layer **11** for spreading the current on the first semiconductor layer **11**. For example, a metal layer can be deposited on the first surface S3 of the semiconductor stack **1** and patterned to form a plurality of contact structures **30**. The material of the contact structure **30** comprises gold (Au), germanium (Ge), beryllium (Be), or an alloy thereof. The shape of the contact structure **30** comprises

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circle or polygon. From the top view of the semiconductor light-emitting device IV of FIG. **10**, the shape of the contact structure **30** is circle and a plurality of contact structures **30** is arranged into a plurality of rows on the semiconductor stack **1**, wherein the plurality of contact structures **30** disposed on adjacent two rows is staggered.

A first reflective layer **331** comprising low refractive index materials is formed on the first surface S3 of the semiconductor stack **1**, and/or between the plurality of contact structures **30**. Furthermore, the plurality of contact structures **30** can be formed between the first reflective layer **331** and the semiconductor stack **1**. Because the refractive index of the group III-V semiconductor materials is between 2 and 4, a material having a refractive index lower than that of the group III-V semiconductor materials is chosen to totally reflect the light emitted from the active layer **10** between the first surface S3 and the first reflective layer **331** for increasing the light extraction efficiency of the semiconductor light-emitting device IV. The low refractive index material comprises oxide, fluoride, or metal oxide. The fluoride comprises magnesium fluoride (MgF_2) or calcium fluoride (CaF_2). Metal oxide comprises titanium oxide (TiO_2), tantalum oxide (Ta_2O_5), tellurium dioxide (TeO_2), yttrium oxide (Y_2O_3), hafnium oxide (HfO_2), aluminum oxide (Al_2O_3), indium zinc oxide (IZO), or indium tin oxide (ITO).

In order to increase the light extraction efficiency of the semiconductor light-emitting device IV, the first surface S3 of the semiconductor stack **1** can be a rough surface and/or a second reflective layer **5** is formed on the first surface S3. The method for forming the rough surface comprises etching, polishing, or printing. The etching method comprises wet etch, such as soaking in acidic or alkaline etching solution, or dry etching, such as ICP. The structure of the second reflective layer **5** can be one or more layers. The material of the second reflective layer **5** comprises metal material with high reflectivity, such as silver (Ag), gold (Au), aluminum (Al), titanium (Ti), chromium (Cr), copper (Cu), nickel (Ni), platinum (Pt), or an alloy thereof. The high reflectivity is 80% or above with respect to the dominant wavelength of the light emitted from the semiconductor light-emitting device III. The second reflective layer **5** is more away from the semiconductor stack **1** than the first reflective layer **331** so the light not reflected by the first reflective layer **331** can be further reflected by the second reflective layer **5**. As shown in FIG. **11** and FIG. **12**, the second reflective layer **5** contacts with the first reflective layer **331** and/or the plurality of contact structures **30** for forming electrical connection when electrical current is injected.

A transparent conductive layer **19** is formed on the second surface S2 of the semiconductor stack **1**. The transparent conductive layer **19** comprises a first side e3 and a second side e4. In a variant of the embodiment, the first side e3 and the second side e4 are approximately planar; in another variant of the embodiment, the second side e4 protrudes the first side e3. The first side e3 of the transparent conductive layer **19** and the side e2 of the semiconductor stack **1** are approximately planar. The transparent conductive layer **19** is electrically connected to the semiconductor stack **1** when the electrical current is injected. The material of the transparent conductive layer **19** comprises transparent material which is transparent to the light emitted from the active layer **10**. In order to reduce the total internal reflection of a light emitted from the active layer **10** on the second surface S2, the transparent conductive layer **19** comprises non group III-V semiconductor material. The refractive index of the material of the transparent conductive layer **19** is lower than that of the semiconductor stack **1**, and the structure of the transparent layer **19** can be one or

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more layers, for example, comprises a first transparent conductive layer **191** and a second transparent conductive layer **192**. Specifically, when the transparent conductive layer is a structure of multi layers, the first transparent conductive layer **191**, which is more away from the semiconductor stack **1** than other transparent conductive layers, comprises material for improving lateral current spreading, for example, indium zinc oxide (IZO). The second transparent conductive layer **192**, which is more closer to the semiconductor stack **1** than other transparent conductive layers, comprises material for forming ohmically contact with the second semiconductor layer **12**, for example, indium tin oxide (ITO).

In order to increase the light extraction efficiency of the semiconductor light-emitting device IV, the second surface **S2** of the semiconductor stack **1** can be a rough surface to reduce total internal reflection. The method for forming the rough surface comprises etching, polishing, or printing. The etching method comprises wet etch, such as soaking acidic or alkaline etching solution, or dry etching, such as ICP.

In other embodiments of the present application, a substrate **8** can be optionally formed on the semiconductor stack **1**. The substrate **8** can be bonded to the second surface **S2** of the semiconductor stack **1** through the transparent conductive layer **19**. The substrate **8** comprises transparent material which is transparent to the light emitted from the active layer **10**, such as gallium arsenide (GaAs), gallium phosphide (GaP), gallium nitride (GaN), sapphire, diamond, glass, quartz, acrylic, zinc oxide (ZnO), or aluminum nitride (AlN). In order to reduce the total internal reflection of the light emitted from the active layer **10** on the interface **S1** between the substrate **8** and the transparent conductive layer **19**, the refractive index of the material of the substrate **8** is smaller than that of the transparent conductive layer **19**, and the refractive index of the transparent conductive layer **19** is between the refractive index of the substrate **8** and the refractive index of the semiconductor stack **1**. Concerning the process yield, a side **e1** of the substrate **8** and the second side **e4** of the transparent conductive layer **19** are approximately planar, and the side **e1** of the substrate **8** protrudes the side **e2** of the semiconductor stack **1**, as shown in FIG. 11.

In an embodiment of the present application, the conductive via **35** extends from the first surface **S3** to the second surface **S2**. As shown in FIG. 10, the conductive vias **35** surrounds the periphery of the semiconductor stack **1** from the top view of the semiconductor light-emitting device IV. As shown in FIG. 11, the conductive via **35** is formed on the side **e2** of the semiconductor stack **1** by removing part of the semiconductor stack **1** such that the conductive via **35** is formed along the side **e2** of the semiconductor stack **1** by penetrating from the first surface **S3** of the semiconductor stack **1**, through the semiconductor stack **1** and exposing an end **351** of the conductive via **35** on a surface of the transparent conductive layer **19**. In an variant of the embodiment, the end **351** of the conductive via **35** extends a depth into the transparent conductive layer **19** (not shown) by removing a part of the semiconductor stack **1** and a part of the transparent conductive layer **19**. When the transparent conductive layer **19** comprises a multi-layer structure, for example, comprises a first transparent conductive layer **191** and a second transparent conductive layer **192**, the end **351** of the conductive via **35** extends into the first transparent conductive layer **191** which is more away from the semiconductor stack **1** than other transparent conductive layers. The electrical current is uniformly distributed in the first transparent conductive layer **191** through the first transparent conductive layer **191** having better lateral current spreading ability than other transparent conductive layers. Then the electrical current is conducted to

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the second semiconductor layer **12** through the second transparent conductive layer **192**. The forming positions of the conductive vias **35** and the contact structure **30** are staggered as shown in FIG. 10 and FIG. 11. A plurality of contact structures **30** is formed on the first surface **S3** of the semiconductor stack **1**, and the conductive via **35** is formed on the side **e2** of the semiconductor stack **1** to surround the plurality of contact structures **30**.

A first insulating layer **361** can be deposited on the semiconductor stack **1** and the conductive via **35** by evaporation. A part of the first insulating layer **361** covering the end **351** of the conductive via **35** and a part of the first insulating layer **361** covering the second reflective layer **5** can be removed through patterning to form a first opening **W1** on the end **351** of the conductive via **35** and expose the transparent conductive layer **19**, and to form a second opening **W2** on the second reflective layer **5** and expose the second reflective layer **5**. The material of the first insulating layer **361** comprises non-conductive material comprising organic materials, such as Sub, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC), polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

As shown in FIG. 11, a conductive material, such as metal, is deposited in the conductive via **35** through evaporation or sputtering to cover the first opening **W1** and part of the first insulating layer **361** to form a connecting layer **4**. The connecting layer **4** comprises a first connecting layer **41** formed in the conductive via **35** and a second connecting layer **42** formed on a side of the first insulating layer **361** opposite to the second reflective layer **5**, wherein the first insulating layer **361** is formed between the semiconductor stack **1** and the first connecting layer **41** to electrically insulate the semiconductor stack **1** and the first connecting layer **41**. From a top view of the semiconductor light-emitting device IV (not shown), the connecting layer **4** can be a patterned structure, for example, line or mesh, formed on the first surface **S3** to electrically connect to the conductive via **35**. As shown in FIG. 11, the connecting layer **4** can be connected to a side of the conductive via **35**, or connected to a plurality of sides of the conductive via **35**. As shown in FIG. 11 and FIG. 12, the connecting layer **4** surrounds the sidewall of the semiconductor stack **1** and connects the transparent conductive layer **192** through the first opening **W1**.

A second insulating layer **362** can be deposited on the semiconductor stack **1** and the conductive via **35** by evaporation. A part of the second insulating layer **362** covering the second connecting layer **42** and a part of the second insulating layer **362** covering the second reflective layer **5** can be removed through patterning to form a third opening **W3** on the second reflective layer **5** and expose the second reflective layer **5**, and to form a fourth opening **W4** on the second connecting layer **42** and expose the second connecting layer **42**. From the top view of the semiconductor light-emitting device IV, the third opening **W3** is larger than the second opening **W2**, the position of the third opening **W3** and the position of the second opening **W2** are overlapped, and the position of the fourth opening **W4** and the position of the first opening **W1** can be overlapped or staggered, as shown in FIG. 8. The material of the second insulating layer **362** comprises non-conductive material comprising organic materials, such as Su8, benzocyclobutene (BCB), perfluorocyclobutane (PFCB), epoxy, acrylic resin, cyclic olefin polymer (COC),

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polymethyl methacrylate (PMMA), polyethylene terephthalate (PET), polycarbonate (PC), polyetherimide, fluorocarbon polymer; inorganic materials, such as silicone, glass; dielectric materials, such as aluminum oxide (Al_2O_3), silicon nitride (SiN_x), silicon oxide (SiO_2), titanium oxide (TiO_2), or magnesium fluoride (MgF_2).

A first pad portion **43** and a second pad portion **53** are formed on the same side of the semiconductor stack **1**. The first pad portion **43** forms on a part surface of the second insulating layer **362** and covers the fourth opening **W4** to electrically connect the connecting layer **4**. In an embodiment of the present application, a metal material is deposited on the fourth opening **W4** and continuously deposited to cover a part surface of the second insulating layer **362** to form the first pad portion **43**. As shown in the cross-sectional view of the semiconductor light-emitting device **IV**, the first pad portion **43** comprises a first face **431** and a second face **432** protruding the first face **431**, wherein the first face **431** and the second face **432** are approximately parallel with the first surface **S3** of the semiconductor stack **1**, a height is formed between the first face **431** and the second face **432**, and the height is larger than or equal to a thickness of the second insulating layer **362**.

As shown in FIG. **11**, a part of the surface of the second reflective layer **5** is not covered by the first insulating layer **361** and/or the second insulating layer **362**, a metal material can be evaporated in the second opening **W2** and/or the third opening **W3**, and continuously deposited along the sidewall of the first insulating layer **361** and/or the sidewall of the second insulating layer **362** to extend onto a part of the second insulating layer **362** to form the second pad portion **53**. As shown in the cross-sectional view of the semiconductor light-emitting device **IV** of FIG. **11**, the second pad portion **53** comprises a first face **531** and a second face **532** protruding the first face **531**, wherein the first face **531** and the second face **532** are approximately parallel with the first surface **S3** of the semiconductor stack **1**. From a top view of the semiconductor light-emitting device **IV**, the connecting layer **4** is formed beyond the region of the second opening **W2** and/or the third opening **W3**. The conductive via **35** surrounds the first pad portion **43** and/or the second pad portion **53**, and the connecting layer **4** is formed in the region of the first pad portion **43** and/or the second pad portion **53**.

An electrical current from external power source can be injected from the first pad portion **43**, and the electrical current is conducted to the second semiconductor layer **12** through the connecting layer **4** and the transparent conductive layer **19**. The material of the first pad portion **43** comprises titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof.

The second pad portion **53** is formed on a part of the contact structure **30**. When an electrical current from external power source is injected into the second pad portion **53**, the second pad portion **53** is electrically connected with the first semiconductor layer **11** through the contact structure **30**. The material of the second pad portion **53** comprises titanium (Ti), platinum (Pt), nickel (Ni), tin (Sn), gold (Au), or an alloy thereof. An area of the first pad portion **43** can be the same as or different from that of the second pad portion **53**.

FIG. **5** illustrates a structure diagram in accordance with another embodiment of the present application. A light bulb **600** comprises an envelope **602**, a lens **604**, a light-emitting module **610**, a base **612**, a heat sink **614**, a connector **616** and an electrical connecting device. The light-emitting module **610** comprises a submount **60** and a plurality of light-emitting devices **608**, which is described in above embodiments, formed on the submount **606**.

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The principle and the efficiency of the present application illustrated by the embodiments above are not the limitation of the application. Any person having ordinary skill in the art can modify or change the aforementioned embodiments. Therefore, the protection range of the rights in the application will be listed as the following claims.

What is claimed is:

1. A semiconductor light-emitting device, comprising:
 - a transparent substrate;
 - a semiconductor stack formed on the transparent substrate, and comprising a first semiconductor layer, and a second semiconductor layer, wherein the second semiconductor layer is closer to the transparent substrate than the first semiconductor layer is to the transparent substrate;
 - a reflective layer formed on the first semiconductor layer;
 - a plurality of conductive vias extending from a surface of the first semiconductor layer to a surface of the second semiconductor layer;
 - a connecting layer formed in the plurality of conductive vias and on the surface of the first semiconductor layer;
 - a first pad portion formed on the semiconductor stack; and
 - a second pad portion formed on the semiconductor stack, wherein a shortest distance between two of the plurality of conductive vias is larger than a shortest distance between the first pad portion and the second pad portion.
2. The semiconductor light-emitting device of claim 1, wherein an area of the first pad portion is different from that of the second pad portion.
3. The semiconductor light-emitting device of claim 1, wherein a space between the first pad portion and the second pad portion ranges between 70 μm and 250 μm .
4. The semiconductor light-emitting device of claim 1, further comprising a first insulating layer comprising a first opening formed on the reflective layer to expose the reflective layer.
5. The semiconductor light-emitting device of claim 1, further comprising a second insulating layer comprising a second opening formed on the reflective layer and a third opening formed on the reflective layer, wherein the second opening of the second insulating layer and the third opening of the second insulating layer are formed on opposite sides of the semiconductor stack.
6. The semiconductor light-emitting device of claim 5, wherein the first pad portion is formed in the second opening of the second insulating layer and extends onto a surface of the second insulating layer; and the second pad portion is formed in the third opening of the second insulating layer and extends onto a surface of the second insulating layer.
7. The semiconductor light-emitting device of claim 1, further comprising a contact structure ohmically contacting the first semiconductor layer, and formed between the first semiconductor layer and the reflective layer.
8. The semiconductor light-emitting device of claim 7, wherein the contact structure comprises metal.
9. A semiconductor light-emitting device, comprising:
 - a transparent substrate;
 - a semiconductor stack formed on the transparent substrate, and comprising a first semiconductor layer and a second semiconductor layer, wherein the second semiconductor layer is closer to the transparent substrate than the first semiconductor layer is to the transparent substrate;
 - a reflective layer formed on the first semiconductor layer;
 - a first insulating layer comprising a first opening formed on the reflective layer;
 - a conductive via surrounding an outer periphery of the semiconductor stack;

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- a connecting layer formed in the conductive via and on a surface of the first semiconductor layer, wherein the first opening of the first insulating layer is surrounded by the connecting layer;
- a second insulating layer comprising a second opening 5 formed on the reflective layer and a third opening formed on the reflective layer, wherein the first opening of the first insulating layer and the second opening of the second insulating layer overlapping, the second opening of the second insulating layer and the third opening of the second insulating layer are formed on opposite sides 10 of the semiconductor stack;
- a first pad portion formed in the second opening of the second insulating layer and extending onto a surface of the second insulating layer; and
- a second pad portion formed in the third opening of the second insulating layer and extending onto a surface of the second insulating layer.
10. The semiconductor light-emitting device of claim 9, 20 further comprising:
- a contact structure ohmically contacting the first semiconductor layer, and formed between the first semiconductor layer and the reflective layer, wherein the first pad portion is electrically connected to the first semiconductor layer through the contact structure, the second pad portion is electrically connected to the second semiconductor layer through the connecting layer.
11. The semiconductor light-emitting device of claim 10, wherein the contact structure comprises metal.

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12. The semiconductor light-emitting device of claim 10, wherein the connecting layer surrounds the contact structures and formed on the contact structure.
13. The semiconductor light-emitting device of claim 9, wherein an area of the first pad portion is different from that of the second pad portion.
14. The semiconductor light-emitting device of claim 9, wherein an area of the first pad portion is the same as that of the second pad portion.
15. The semiconductor light-emitting device of claim 9, wherein the first pad portion or the second pad portion comprises a first face and a second face protruding the first face, a height is between the first face and the second face, and the height is equal to a thickness of the second insulating layer.
16. The semiconductor light-emitting device of claim 9, wherein the material of the reflective layer comprises metal or metal oxide.
17. The semiconductor light-emitting device of claim 9, wherein a space between the first pad portion and the second pad portion ranges between 70 μm and 250 μm .
18. The semiconductor light-emitting device of claim 9, wherein the connecting layer is formed on the reflective layer.
19. The semiconductor light-emitting device of claim 9, wherein the third opening of the second insulating layer exposes the connecting layer.
20. The semiconductor light-emitting device of claim 9, wherein the connecting layer is formed on the surface of the first semiconductor layer beyond a region of the first opening of the first insulating layer.

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